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MECHANICAL PROPERTIES OF CENTRAL SIERRA OLD-GROWTH AND SECOND-GROWTH INCENSE CEDAR

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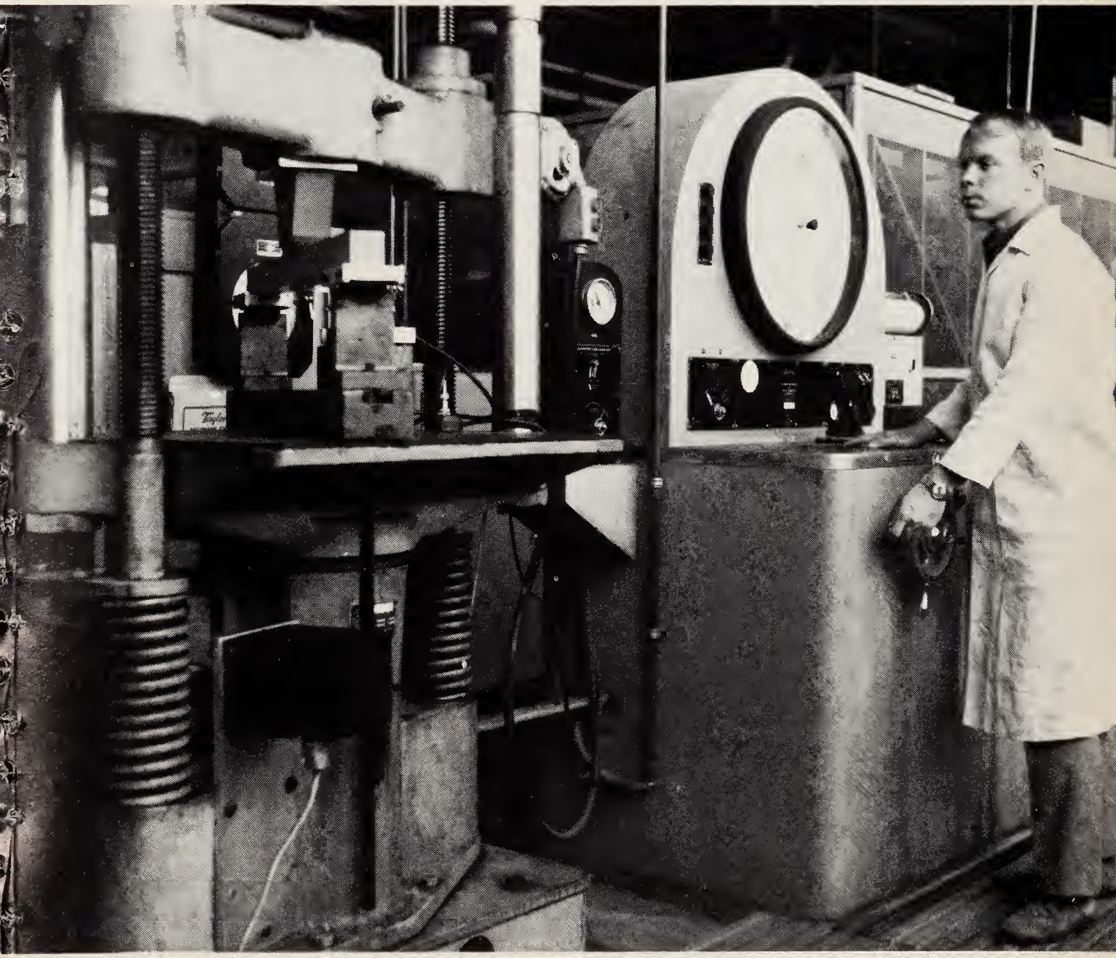

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This bulletin reports the results of strength tests and density, shrinkage and fiber measurements on wood of some old-growth and second-growth incense cedar trees from the central Sierra. It compares these values with those of other softwoods and concludes that incense cedar wood is satisfactory for use as construction material and for pulpwood.

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TABLE 1

AGE AND SIZE OF TREES, AND LOCATION AND SIZE OF TEST BOLTS

Tree number	Approximate age	D. B. H. *	Total height	Log location and size			
				Large end		Small end	
				Height	D. I. B.†	Height	D. I. B.
	years	*inches*	*feet*	*feet*	*inches*	*feet*	*inches*
1	160	31.5	120	11.5	23.8	20.5	21.7
2	139	19.5	76	7.5	15.7	21.3	13.3
6	220	26.0	97	7.5	21.4	20.5	18.9
10	278	29.0	92	8.0	22.0	17.0	20.4
11	53	17.0	70	10.0	11.5	23.5	9.0
12	53	13.0	50	4.5	11.0	18.0	8.5
13	42	12.8	46	4.5	11.5	18.0	8.0
14	51	18.0	60	9.0	12.3	18.0	10.2
15	49	17.0	60	8.5	12.3	17.5	11.0
16	51	17.5	68	8.9	12.9	17.9	11.7

* Diameter outside bark 4.5 feet above ground.
† Diameter inside bark.

MECHANICAL PROPERTIES OF CENTRAL SIERRA OLD-GROWTH AND SECOND-GROWTH INCENSE CEDAR[1]

INTRODUCTION

Incense cedar (*Libocedrus decurrens* Torr.), which in recent years has been the principal source of wood for pencil slats, originally was one of the least important commercial species found in the mixed conifer forests of the Sierra Nevada, the Coast Ranges, and the southern Cascades. Much of the incense cedar in these forests was infected by brown pocket-rot fungus (*Polyporus amarus* Hedg.) which caused the trees to be rated as the most defective of all the associated Sierra conifers; the average cull was reported to be 21 per cent for mature dominants and 68 to 77 per cent for overmature dominants (Fowells, 1965). As a result, incense cedar—along with white fir [*Abies concolor* (Gord. & Glend.) Lindl.]—was long regarded as inferior, and with the advent of selective logging with tractors most cedars were left uncut. Having long had only local value (for uses such as posts and mudsills because of its durable heartwood) and little importance for lumber and related uses, scant attention was given to assessing incense cedar's physical and mechanical properties. In recent years, however, old-growth incense cedar has increased in value because new uses (such as for pencil slats and rustic siding) have reduced the volume of standing timber. Fortunately, the supply of young-growth incense cedar will probably also increase because the species appears likely to be relatively more aboundant as a component of second-growth Sierra forests.

OBJECTIVES

The data on the mechanical properties of incense cedar (available in USDA Technical Bulletin No. 479) were obtained from four trees from Lane County, Oregon, near the northern limit of the tree's range, and from additional material, tree sources unknown, from Weed, California; both these areas are in the southern Cascades (Markwardt and Wilson, 1935). The green values given in Bulletin 479 are essentially identical to those first reported by the Forest Service in 1917 (Newlin and Wilson, 1917). Because of limited published data available on old-growth, and none at all on young-growth, it seemed worthwhile to gather additional data on the wood properties of this increasingly important species. In 1965, a study was made on variation in wood quality of 12 incense cedar trees from the University of California's Blodgett Forest—this is a 3,000-acre University of California research forest east of Auburn, California, at approximately 4,300 feet elevation. The study described variations and interrelationships of specific gravity, radial and tangential shrinkage, percentage of heartwood, growth-ring width, and percentage of summerwood (Resch and Huang, 1967). Our study reports on the mechanical properties of four older trees used in the 1965 study, and on the same properties of six second-growth trees also obtained from Blodgett Forest. Data on fiber-length were also obtained for two of the old-growth and three of the second-growth trees.

MATERIALS AND METHODS

Four-foot bolts were cut from the trees in general conformity with the procedure prescribed in American Society for Testing and Materials Designation D 143–52. The location of bolts with respect to height in tree was adjusted when advantageous to obtain a maximum of clear length. Although no tree was sampled to test for variation with respect to height, an additional 4-foot bolt was obtained for two of the old-growth and three of the second-growth trees. Table 1 gives general information on the trees.

The $2\frac{1}{2} \times 2\frac{1}{2}$-inch test blanks were pre-

[1] Submitted for publication January 28, 1971.

pared in accordance with the ASTM designation and assembled at time of preparation into two groups, one to be tested green and the other dry. Because incense cedar is tolerant and retains its branches for many years, the wood was quite knotty; this necessitated departing from the prescribed sampling procedure by utilizing some clear material located in sectors of the log adjacent to cardinal direction zones. Even with these additional blanks, however, there was a shortage of specimens for some dry tests of second-growth trees.

All the mechanical properties tests and specific gravity and volumetric shrinkage determinations conformed to ASTM D 143–52. Shrinkage measurements were made to the nearest 0.001-inch on 1 × 1 × 4-inch specimens cut with growth rings aligned so as to parallel tangential and radial directions. On these blocks the longitudinal shrinkage was measured over the 4-inch dimension, and tangential and radial shrinkage was determined from measurements taken in the middle of the 4-inch surfaces.

Data on fiber length were obtained by macerating matchstick-size samples of wood with an aqueous solution of 10 per cent nitric and 10 per cent chromic acids, and then staining with safranin and mounting directly on slides in dilute polyvinyl acetate. Averages were based on 40 measurements of fibers selected at random from slides prepared for each sample (Echols, 1969).

RESULTS AND DISCUSSION

Table 2 lists basic data for tests on green specimens of old-growth trees, and table 3 lists data on second-growth. Table 4 gives basic data for dry specimens of old-growth, and table 5 lists them for second-growth. As the number of tests on each property varied for the different trees, mean values in the tables were determined from tree means rather than from individual test values in order to give each tree-test equal weight (Cockrell, 1959).

Moisture content. Old-growth green wood moisture content values ranged from 30 to 45 per cent for heartwood to 160 to 225 per cent for sapwood. Second-growth sapwood moisture content values ranged from 200 to 280 per cent, with most specimens being higher than the maximum for the old-growth. Second-growth heartwood moisture content was similar to the old-growth. The moisture content of air-dry test material for the old-growth trees and second-growth trees numbered 14, 15, 16 was approximately 12 per cent. Air-dry specimens of second-growth trees 11, 12, 13 had about 15 per cent moisture content and were adjustd to 12 per cent according to the U. S. Forest Products Laboratory exponential formula using an intersection point (Mp value) of 25 (USDA, 1955).

Growth rate. The growth rate of old-growth test material ranged from 8 to 28 rings per inch, with most specimens ranging from 15 to 20. Most second-growth specimens varied between 4 to 9 rings per inch, and in all cases the specimens farthest from the pith had the slowest growth rate. Figures 1 and 2 (page 8) illustrate the trend of decreasing ring width from pith to bark in trees 1 and 14. In tree 1, bolt A—which had 149 rings in the cross section—the average radial thickness of the first 50 rings from the pith was 6 inches and, for the last 50 rings, 2.5 inches. For tree 2, bolt A, the corresponding figures are 123 rings total, 4.15 inches first 50 rings, and 2.15 inches last 50 rings.

Structural qualities. Comparison of table 2 with table 3, and of table 4 with table 5, shows that wood from second-growth incense cedar 50 years old or less is appreciably weaker than old-growth. Particular note should be taken of the lower bending and compression parallel values of tree 13 (tables 3 and 5). This tree was younger (37 rings at 4.5 feet height) than the other five, and its test specimens included a higher percentage of juvenile wood (wood closer to the pith). Inspection of bending-strength data for individual old-growth specimens close to the pith revealed that these all had lower values than those farther from the pith and, as previously reported for Monterey pine (Cockrell, 1959), the central core wood was less dense and weaker than material farther out in the cross-section. Table 6 compares data on old-growth and second-growth material used in this study with previously reported U. S. Forest Service data

Table 2

MECHANICAL PROPERTIES OF GREEN OLD-GROWTH INCENSE CEDAR

Property	Tree number, number of specimens tested, and magnitude of property				Species mean	Standard deviation of tree means	Minimum individual test value	Maximum individual test value
	Tree number							
	1	2	6	10				
Specific gravity:	(8)†	(7)	(14)	(5)				
Volume green, weight oven-dry	0.34	0.38	0.33	0.37	0.36	0.02	0.31	0.42
Volume oven-dry, weight oven-dry	0.37	0.42	0.36	0.40	0.39	0.03	0.34	0.46
Static bending:	(14)	(14)	(18)	(5)				
Fiber stress at proportional limit (psi)*	3,860.0	4,640.0	3,810.0	5,110.0	4,360.0	631.0	3,150.0	5,930.0
Modulus of rupture (psi)	6,620.0	7,850.0	6,310.0	7,910.0	7,170.0	827.0	4,940.0	8,720.0
Modulus of elasticity (1,000 psi)	923.0	1,160.0	765.0	1,190.0	1.010	202.0	396.0	1,370.0
Work to proportional limit (in.-lb. per cu. in.)	0.92	1.09	1.08	1.14	1.06	0.10	0.60	1.71
Work to maximum load (in.-lb. per cu. in.)	7.2	11.0	9.2	12.0	9.8	2.1	4.6	14.9
Total work (lb. per cu. in.)	10.3	18.0	12.7	23.4	16.1	5.8	4.6	25.7
Compression parallel to grain:	(24)	(21)	(32)	(9)				
Stress at proportional limit (psi)	3,010.0	3,690.0	2,790.0	3,390.0	3,220.0	399.0	1,940.0	4,380.0
Maximum crushing strength (psi)	3,340.0	4,070.0	3,180.0	3,780.0	3,590.0	407.0	2,450.0	4,600.0
Compression perpendicular to grain:	(10)	(8)	(16)	(5)				
Stress at proportional limit (psi)	300.0	340.0	300.0	350.0	320.0	26.0	240.0	420.0
Toughness:	(29)	(23)	(47)	(26)				
(in. lb.)	104.0	146.0	122.0	104.0	119.0	20.0	51.0	329.0
Hardness:	(40)	(40)	(60)	(36)				
Side (lb.)	380.0	470.0	370.0	420.0	410.0	45.0	270.0	570.0
	(20)	(20)	(30)	(18)				
End (lb.)	570.0	660.0	570.0	610.0	600.0	43.0	480.0	830.0
Maximum shearing strength parallel to grain	(25)	(29)	(27)	(18)				
(psi)	760.0	880.0	800.0	810.0	810.0	50.0	630.0	970.0
Cleavage	(24)	(20)	(32)	(13)				
(lb. per in. of width)	170.0	190.0	170.0	180.0	180.0	10.0	120.0	240.0
Maximum tensile strength perpendicular to grain	(14)	(12)	(25)	(12)				
(psi)	290.0	380.0	330.0	380.0	340.0	44.0	220.0	460.0
Maximum tensile strength parallel to grain	(8)	(9)	(11)	(5)				
(psi)	11,360.0	11,110.0	6,780.0	10,880.0	10,030.0	2,180.0	4,410.0	14,240.0

* Pounds per square inch.

† Numbers in parentheses refer to number of specimens tested for each property.

Table 3

MECHANICAL PROPERTIES OF GREEN SECOND-GROWTH INCENSE CEDAR

Property	Tree number, number of specimens tested, and magnitude of property						Species mean	Standard deviation of tree means	Minimum individual test value	Maximum individual test value
	Tree number									
	11	12	13	14	15	16				
Specific gravity:	(2)†	(1)	(3)	(8)	(8)	(9)				
Volume air-dry, weight oven-dry	0.34	0.30	0.28	0.31	0.32	0.29	0.30	0.01	0.28	0.37
Volume oven-dry, weight oven-dry	0.34	0.33	0.31	0.34	0.35	0.32	0.33	0.01	0.30	0.40
Static bending:	(6)	(8)	(5)	(8)	(9)	(8)				
Fiber stress at proportional limit (psi)*	3,870.0	3,900.0	2,620.0	2,770.0	3,180.0	2,650.0	3,160.0	592.0	1,840.0	4,590.0
		(7)								
Modulus of rupture (psi)	6,070.0	5,610.0	4,280.0	5,850.0	5,890.0	5,300.0	5,500.0	654.0	3,940.0	6,510.0
		(8)								
Modulus of elasticity (1,000 psi)	748.0	598.0	354.0	714.0	745.0	675.0	639.0	150.0	294.0	900.0
		(8)								
Work to proportional limit (in.-lb. per cu. in.)	1.18	1.47	1.08	0.60	0.80	0.58	0.95	0.35	0.32	1.87
		(7)								
Work to maximum load (in.-lb. per cu. in.)	7.4	7.1	10.3	8.0	6.8	5.0	7.4	1.7	4.1	12.7
		(7)								
Total work (lb. per cu. in.)	8.6	10.8	10.5	12.6	10.0	5.0	9.6	2.6	4.1	18.4
Compression parallel to grain:	(5)	(4)	(4)	(11)	(12)	(12)				
Stress at proportional (psi)	2,800.0	2,590.0	1,330.0	2,500.0	2,650.0	2,390.0	2,380.0	532.0	1,250.0	3,190.0
Maximum crushing strength (psi)	3,020.0	2,930.0	2,040.0	2,860.0	2,980.0	2,700.0	2,760.0	368.0	1,910.0	3,220.0
Compression perpendicular to grain:	(6)	(5)	(4)	(7)	(7)	(8)				
Stress at proportional limit (psi)	260.0	260.0	260.0	300.0	290.0	230.0	270.0	25.0	190.0	340.0
Toughness:	(9)	(12)	(17)	(22)	(28)	(25)				
(in. lb.)	100.0	135.0	136.0	180.0	184.0	100.0	139.0	27.0	65.0	315.0
Hardness:	(7)	(6)	(5)	(8)	(8)	(8)				
Side (lb.)	300.0	320.0	310.0	370.0	360.0	280.0	320.0	35.0	250.0	480.0
End (lb.)	470.0	490.0	460.0	500.0	520.0	460.0	480.0	25.0	420.0	600.0
Maximum shearing strength parallel to grain	(6)	(8)	(5)	(14)	(16)	(13)				
(psi)	710.0	730.0	710.0	760.0	790.0	710.0	740.0	33.0	620.0	960.0
Cleavage	(11)	(11)	(5)	(14)	(18)	(18)				
(lb. per in. of width)	180.0	180.0	160.0	160.0	170.0	170.0	170.0	9.0	110.0	230.0
Maximum tensile strength perpendicular to grain	(10)	(12)	(9)	(15)	(15)	(18)				
(psi)	310.0	310.0	330.0	320.0	310.0	310.0	320.0	8.0	240.0	410.0
Maximum tensile strength parallel to grain	(3)	(4)	(7)	(6)	(6)	(6)				
(psi)	9,110.0	10,400.0	6,060.0	8,270.0	7,780.0	7,900.0	8,250.0	1,450.0	4,550.0	11,440.0

* Pounds per square inch.
† Numbers in parentheses refer to number of specimens tested for each property.

Table 4

MECHANICAL PROPERTIES OF DRY OLD-GROWTH INCENSE CEDAR

Property	Tree number, number of specimens tested, and magnitude of property — Tree number 1	2	6	10	Species mean	Standard deviation of tree means	Minimum individual test value	Maximum individual test value
Specific gravity:								
Volume green, weight oven-dry	0.34	0.38	0.33	0.37	0.36	0.02	0.31	0.42
Volume oven-dry, weight oven-dry	0.37	0.42	0.36	0.40	0.39	0.03	0.34	0.46
Static bending:	(13)†	(7)	(9)	(10)				
Fiber stress at proportional limit (psi)*	5,530.0	6,050.0	5,670.0	5,430.0	5,670.0	272.0	4,200.0	7,090.0
Modulus of rupture (psi)	8,440.0	10,480.0	8,640.0	9,620.0	9,300.0	943.0	6,090.0	12,180.0
Modulus of elasticity (1,000 psi)	1,070.0	1,350.0	951.0	1,210.0	1,150.0	173.0	780.00	1,630.0
Work to proportional limit (in.-lb. per cu. in.)	1.63	1.58	1.89	1.39	1.62	0.21	1.0	2.35
Work to maximum load (in.-lb. per cu. in.)	6.2	9.1	8.1	9.1	8.1	1.4	2.7	16.8
Total work (in.-lb. per cu. in.)	7.2	13.0	8.1	10.4	9.7	2.6	2.7	20.6
Compression parallel to grain:	(27)	(9)	(18)	(16)				
Stress at proportional limit (psi)	4,170.0	5,040.0	3,680.0	4,390.0	4,320.0	564.0	2,620.0	5,750.0
Maximum crushing strength (psi)	5,120.0	6,570.0	4,890.0	5,700.0	5,570.0	749.0	3,790.0	6,880.0
Compression perpendicular to grain:	(19)	(7)	(12)	(12)				
Stress at proportional limit (psi)	540.0	700.0	580.0	630.0	610.0	69.0	280.0	950.0
Toughness:	(14)	(5)	(13)	(12)				
(in. lb.)	92.0	142.0	118.0	122.0	118.0	21.0	48.0	243.0
Hardness:	(64)	(24)	(44)	(52)				
Side (lb.)	410.0	500.0	400.0	470.0	440.0	48.0	330.0	590.0
En	(36)	(12)	(22)	(26)				
End (lb.)	700.0	830.0	760.0	860.0	790.0	72.0	620.0	1,000.0
Maximum shearing strength parallel to grain	(22)	(9)	(16)	(9)				
(psi)	910.0	1,040.0	970.0	1,110.0	1,010.0	87.0	750.0	1,540.0
Cleavage	(25)	(11)	(19)	(11)				
(lb. per in. of width)	140.0	160.0	150.0	160.0	150.0	10.0	100.0	220.0
Maximum tensile strength perpendicular to grain	(28)	(11)	(18)	(18)				
(psi)	260.0	250.0	270.0	280.0	260.0	13.0	180.0	400 0
Maximum tensile strength parallel to grain	(6)	(3)	(5)	(7)				
(psi)	12,380	13,400	10,160	11,960	11,960	1,350.0	8,190.0	15,260.0

* Pounds per square inch.
† Numbers in parentheses refer to number of specimens tested for each property.

Fig. 1. Cross section of old-growth tree 1 at large end of log.

for incense cedar, Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco], and white fir (comparison was on the basis of certain mechanical properties). Douglas fir is included because its working stresses for construction uses such as joists, planks, studs and framing are the highest of western softwoods (Western Wood Products Assoc., 1968). White fir is included among the true firs which (with hemlock) are in the next highest working stress (design value) species category. The values for old-growth material tested in our study are consistently higher than those reported by the Forest Service in 1917 and 1935 and, except for stiffness (modulus of elasticity) of the dry wood, they compare favorably with white fir—which is generally accepted

Fig. 2. Cross sections of young-growth tree 14 at large and small end of first 4-foot bolt.

Table 5

MECHANICAL PROPERTIES OF DRY SECOND-GROWTH INCENSE CEDAR

Property	Tree number, number of specimens tested, and magnitude of property						Species mean	Standard deviation of tree means	Minimum individual test value	Maximum individual test value
	Tree number									
	11	12	13	14	15	16				
Specific gravity:	(2)†	(1)	(3)	(8)	(8)	(9)				
Volume air-dry, weight oven-dry	0.31	0.30	0.28	0.31	0.32	0.29	0.30	0.01	0.28	0.37
Volume oven-dry, weight oven-dry	0.34	0.33	0.31	0.34	0.35	0.32	0.33	0.01	0.30	0.40
Static bending:	(4)	(4)	(5)	(1)	(2)	(3)				
Fiber stress at proportional limit (psi)*	5,250.0	5,280.0	2,650.0	5,140.0	5,220.0	4,220.0	4,630.0	1,049.0	2,360.0	6,140.0
Modulus of rupture (psi)	7,430.0	7,570.0	5,450.0	8,790.0	8,340.0	6,500.0	7,350.0	1,220.0	5,040.0	8,790.0
Modulus of elasticity (1,000 psi)	850.0	824.0	368.0	909.0	931.0	851.0	789.0	210.0	315.0	946.0
Work to proportional limit (in.-lb. per cu. in.)	1.81	1.89	1.07	1.61	1.82	1.16	1.56	0.36	0.89	2.54
Work to maximum load (in.-lb. per cu. in.)	6.2	7.2	10.4	8.0	6.0	3.8	6.9	2.2	4.2	13.4
Total work (in.-lb. per cu. in.)	7.0	9.4	10.4	9.4	7.8	3.8	8.0	2.4	4.2	16.0
Compression parallel to grain:	(4)	(4)	(4)							
Stress at proportional (psi)	3,370.0	2,670.0	1,300.0	....	....	....	2,450.0	1,053.0	1,120.0	3,560.0
Maximum crushing strength (psi)	4,110.0	3,900.0	2,860.0	....	....	....	3,620.0	669.0	2,780.0	4,320.0
Compression perpendicular to grain:	(4)	(3)	(5)							
Stress at proportional limit (psi)	320.0	500.0	420.0	....	....	....	410.0	90.0	280.0	580.0
Toughness:	(15)	(9)	(10)	(16)	(25)	(25)				
(in. lb.)	94.0	102.0	106.0	120.0	98.0	78.0	100.0	14.0	50.0	147.0
Hardness:	(5)	(3)	(5)	(2)	(2)	(4)				
Side (lb.)	340.0	460.0	360.0	470.0	460.0	340.0	400.0	64.0	320.0	530.0
End (lb.)	700.0	760.0	650.0	740.0	800.0	600.0	720.0	59.0	620.0	820.0
Maximum shearing strength parallel to grain	(10)	(7)	(5)	(4)	(4)	(4)				
(psi)	850.0	990.0	930.0	1,030.0	1,060.0	940.0	970.0	76.0	730.0	1,260.0
Cleavage	(9)	(4)	(6)	(2)		(8)				
(lb. per in. of width)	160.0	140.0	140.0	160.0	....	160.0	150.0	11.0	110.0	200.0
Maximum tensile strength perpendicular to grain	(11)	(6)	(5)	(2)		(2)				
(psi)	230.0	310.0	280.0	270.0	....	270.0	270.0	29.0	160.0	400.0
Maximum tensile strength parallel to grain	(4)	(7)	(6)	(2)	(4)	(10)				
(psi)	10,780.0	9,490.0	5,350.0	8,440.0	7,500.0	6,320.0	7,980.0	2,012.0	4,400.0	13,130.0

* Pounds per square inch.
† Numbers in parentheses refer to number of specimens tested for each property.

TABLE 6

INCENSE CEDAR DATA OBTAINED IN THIS STUDY COMPARED WITH PREVIOUSLY REPORTED DATA ON INCENSE CEDAR AND WHITE AND DOUGLAS FIRS*

Specimens	Specific gravity‡	Modulus of rupture	Modulus of elasticity	Total work	Maximum crushing strength	Compression perpendicular to grain	Hardness		Shear	Cleavage
							End	Side		
		psi	*1,000 psi*	*in.-lb. per cu. in.*	*psi*		*lb.*		*psi*	*lb. per cu. in. of width*
Green:										
Incense cedar old-growth	0.36	7,170	1,010	16.1	3,590	320	600	410	810	180
Incense cedar second-growth	0.30	5,500	639	9.6	2,760	270	480	320	740	170
Incense cedar†	0.35	6,200	840	8.8	3,150	460	570	390	830	160
White fir†	0.35	5,700	1,030	11.4	2,710	370	380	330	750	170
Douglas fir†	0.45	7,600	1,550	19.2	3,890	510	510	480	930	160
Dry:										
Incense cedar old-growth	0.38	9,300	1,150	9.7	5,570	610	790	440	1,010	150
Incense cedar second-growth	0.32	7,350	789	8.0	3,620	410	720	400	970	150
Incense cedar†	0.37	8,000	1,040	8.2	5,200	730	830	470	880	...
White fir†	0.37	9,300	1.380	11.4	5,350	600	730	440	930	160
Douglas fir†	0.48	11,700	1,920	22.9	7,420	910	760	670	1,140	180

* Previously reported data obtained from U. S. D. A. Tech. Bul. **479**.
† Previously reported data.
‡ Based on volume at test and weight oven-dry.

TABLE 7

SHRINKAGE PER CENT OF SECOND-GROWTH AND OLD-GROWTH INCENSE CEDAR

Item	Total number of samples tested	Type and condition of wood and type and amount* of shrinkage								
		Heartwood								
		Green to air-dry				Green to oven-dry				
		Longitudinal†	Tangential	Radial	T/R‡	Longitudinal†	Tangential	Radial	T/R‡	Volumetric
Old-growth:										
Average......	4	−0.01	2.0	1.1	1.8	0.13	4.0	2.4	1.7	6.5
Standard deviation......		0.03	0.2	0.05	0.2	0.05	0.3	0.1	0.2	0.2
Second-growth:										
Average......	2	−0.07	1.7	0.8	2 1	0.10	3.1	1.7	1.8	6.0
Standard deviation......		0.03	0.5	0.1	0.1	0.06	0.7	0.2	0.2	0.2
		Sapwood								
Old-growth:										
Average......	4	−0.05	3.0	1.8	1.7	0.07	6.1	3.8	1.7	9.4
Standard deviation......		0.03	0.4	0.3	0.3	0.04	0.7	0.5	0.1	0.8
Second-growth:										
Average......	6	−0.05	2.9	1.2	2.4	0.08	5.6	2.8	2.0	9.0
Standard deviation......		0.06	0.4	0.2	0.3	0.06	0.3	0.3	0.3	0.3

* In per cent
† Negative values = elongation
‡ T/R = ratio of tangential to radial shrinkage

as satisfactory for most construction uses (dimension lumber).

Shrinkage. Table 7 presents data on longitudinal, tangential, radial, and volumetric shrinkage. The data show that tangential, radial, and volumetric shrinkage of heartwood is conspicuously less than that of sapwood; averages of tangential and radial shrinkage for the oven-dry condition of old-growth (heartwood and sapwood combined) are 5.0 and 3.1 per cent, respectively, and are approximately the same as those reported by Resch and Huang in 1967 for their larger sample of 11 trees. Tangential, radial and volumetric shrinkage percentages for second-growth are somewhat lower than those for old-growth, while the T/R ratios (ratio of tangential to radial shrinkage) are somewhat higher. Practically all specimens elongated slightly when dried to 12 per cent (air-dry), but showed slight net shrinkage when drying continued to the oven-dry condition.

Fiber length. Figure 3 shows the relationship of fiber length to number of rings from pith for two old-growth and three second-growth trees. The basic data suggest that at 20 rings from the pith the average length is about 3 millimeters, with minimum and maximum values being approximately 1.5 mm and 4 mm, respectively. Beyond 30 rings from the pith, the average length is about 3.5 mm, with minimum and maximum values being about 1.5 mm and 5.0 mm.

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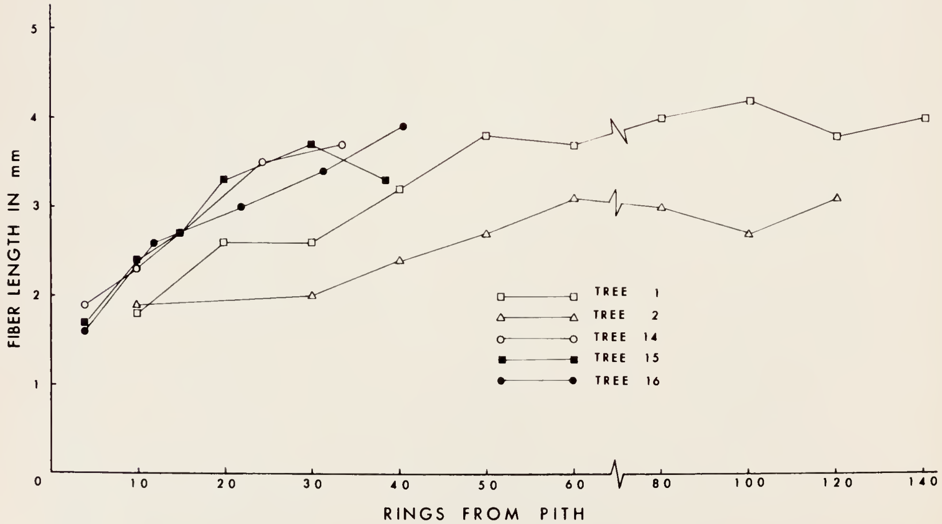

Fig. 3. Relationship of fiber length to rings from pith at large end of logs of two old-growth and three young-growth trees.

SUMMARY

Strength and some other physical properties data of wood are reported for a sampling of old-growth and second-growth incense cedar trees from the central Sierra. These data indicate that old-growth incense cedar wood compares favorably with white fir wood in all mechanical properties save for being slightly lower in stiffness. Data for second-growth incense cedar in the 50-year-old class indicate that it is lighter and weaker than old-growth. In the green condition it is essentially equal to white fir in all strength properties except for being distinctly lower in stiffness; in the air-dry condition it is also somewhat weaker in bending. Tangential, radial, and volumetric shrinkage of heartwood was distinctly less than in sapwood, and this species would be classed with redwood as being among those softwoods with the least shrinkage. Fibers are about same length as the average of important pulpwood species. The wood is suitable for light construction and the fibers for wood pulp.

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